

BODY BURDEN OF CHROMIUM
IN BALTIMORE HARBOR BLUE CRABS:
RESULTS OF JULY 1986 SURVEY

Prepared for

Allied Corporation
Baltimore, Maryland

Prepared by

EA Engineering, Science, and Technology, Inc.
Sparks, Maryland

J. Charles Baummer, Jr.
J. Charles Baummer, Jr., Ph.D.
Project Manager

9 Feb 1987
Date

James J. Gift
James J. Gift, Ph.D.
Senior Vice President

9 Feb 1987
Date

February 1987

1. INTRODUCTION

The Risk Assessment of the remedial investigation report for the Allied Baltimore Works (EA 1986) included an investigation of chromium body burdens in blue crabs from Baltimore Harbor based upon sampling performed in October 1985. That survey found that the chromium body burdens of Baltimore Harbor blue crabs were within the range reported for blue crabs and for other edible species along the Atlantic and Gulf Coasts of the United States; the observed chromium levels were below the level suggested by Eisler (1986) as presumptive evidence of chromium contamination. Apparent spatial differences in body burden exist in the 1985 survey data, but they could not be confirmed with statistical confidence because of differences in the size and number of crabs caught among stations.

As a result of these limitations, the survey was repeated in July of 1986. Sampling locations (Figure 1) and methods were the same as described by EA (1986), except that sediment sampling and analysis were not included in the 1986 survey.

2. RESULTS

Total chromium crab body burden (in muscle tissue "picked" from the exoskeleton after the crabs were steamed) and water column concentrations (vertical composites taken on the first and second days of sampling) of total and hexavalent chromium were determined at 10 stations in the Patapsco River and Chesapeake Bay (Figure 1). Mean values for these data are presented in Table 1. Sediment chromium concentrations from the October 1985 collection are also presented in this table for ease of reference.

3. DISCUSSION

3.1 CRAB BODY BURDEN

Wet and dry weight data for blue crab chromium body burden (Tables 2 and 3, respectively) are significantly different among stations based on ANOVA results ($p < 0.0001$). Tukey's Studentized Range Test indicates that total chromium body burden values obtained for Station 2 are significantly higher than values obtained from the other stations ($p < 0.05$). Body burden values based on wet weight and dry weight data are highly correlated ($r = 0.98$, $p < 0.0001$, $n = 10$).

Station 2 near the Allied Plant (Figure 1) exhibited the highest blue crab body burden. This station also had the greatest hexavalent chromium concentration in the water column, and the greatest concentrations of hexavalent and total chromium in the sediment.

3.2 WATER COLUMN CONCENTRATIONS

Two water samples were collected from each station for analysis of hexavalent and total chromium concentrations. ANOVA results indicate that hexavalent chromium concentrations were significantly different among stations ($p < 0.0002$). Tukey's test indicates that Station 2 had significantly higher ($p < 0.05$) hexavalent chromium concentrations than the other nine stations (Table 4). In fact, hexavalent chromium concentrations were at or below the detection limit for all stations except Station 2. Total chromium concentrations were not statistically different among stations based on ANOVA results ($p = 0.2573$) (Table 5). Similarly, Tukey's test does not indicate differences in total chromium between stations ($p < 0.05$). However, the large variation between total chromium values for the two samples collected at Station 2 limits the ability to discern statistical differences in total chromium between stations. Of the two samples collected, the initial sample yielded a total chromium concentration of 0.07 mg/L whereas the concentration found was in the next day's sample 0.54 mg/L. The former value is comparable to values obtained from samples collected at Stations 1 and 3, whereas the latter value is approximately 8 times greater than the next lower value.

3.3 RELATIONSHIP BETWEEN BLUE CRAB BODY BURDEN AND WATER COLUMN CONCENTRATIONS

As discussed earlier, wet and dry weight body burdens at Station 2 were significantly greater than the values for the other nine stations. Similarly, hexavalent chromium in the water column was significantly higher at Station 2. Based on these data and correlation analysis performed on the mean values, there appears to be a relationship between hexavalent chromium in the water column, and wet- and dry-weight total chromium body burden in blue crabs (Table 6). Similar correlations appear to exist between body burdens and the total chromium concentration in the water column.

3.4 COMPARISON WITH OTHER DATA

3.4.1 October 1985 Survey

Data for samples collected in July 1986 are similar to data from samples collected by EA in October 1985. The unexplained elevation in body burden levels at Stations 8 through 10, relative to Stations 5 through 7, observed in October's samples was not evident in July's samples, however. Similarly, water column concentrations of hexavalent and total chromium were similar for both survey periods. In both surveys, hexavalent chromium was above the detection limit only at Station 2.

3.4.2 Other Studies

The Risk Assessment document (EA 1986), contains a comparison of the chromium body burdens observed in the October 1985 survey with existing blue crab data for Chesapeake Bay, Baltimore Harbor, Assawoman Bay, and other sites on the Atlantic and Gulf coasts of the United States. The document also includes a discussion of reported chromium body burdens

from other species. Generally, data for blue crabs from the Northwest Branch of the Patapsco River appear similar to chromium body burden data for blue crabs and other edible species collected over a larger geographical area (Atlantic and Gulf Coasts of the United States). As a result of the similarity of values obtained in July 1986 and October 1985, the comparison with values in the literature contained in the risk assessment document (EA 1986) remains applicable and should be consulted for specific information. The evaluation of risk to humans associated with crab consumption (EA 1986) was based on the average body burden of crabs from Stations 1-4 in the Northwest Branch (0.37 mg/kg wet-weight basis). In the present study, the average for these same stations (0.27 mg/kg) is not substantially different. Thus the conclusions of the Risk Assessment are not affected by the more recent findings.

3.4.3 Sediment Data

Sediment samples were not collected during the July 1986 survey. Based on the assumption that sediment concentrations of chromium would not change appreciably in the period between the October 1985 and July 1986 surveys, certain comparisons between October's sediment data and July's water and crab tissue data seem reasonable. Generally, as shown in Table 6, the total chromium concentration of the sediment is correlated with both wet and dry weight chromium body burdens of the blue crab, whereas levels of hexavalent chromium in the sediment are correlated with wet weight body burdens only. Similarly, total chromium concentrations in water samples are correlated with sediment total and hexavalent chromium concentrations. Hexavalent chromium concentrations in the water samples do not appear to be related to sediment chromium concentrations.

4. SUMMARY

The Risk Assessment for the remedial investigation of the Allied Baltimore Works (EA 1986) included a discussion of chromium body burdens in blue crabs collected from Baltimore Harbor in October 1985. Apparent spatial differences in body burdens were found, but they could not be confirmed because of differences in the size and number of crabs caught among the stations. Because of these limitations, the survey was repeated in July 1986. The findings of the second survey are presented in this report.

In July 1986, the chromium body burdens were significantly higher at Station 2 near the Allied plant than at the other stations. The concentrations of hexavalent chromium in the water column exhibited a similar pattern, and were positively correlated with the body burdens. However, the findings of the present study do not alter the conclusions of the Risk Assessment regarding blue crabs:

- the body burdens of chromium in Baltimore Harbor blue crabs are within the range reported for blue crabs and other edible species along the Atlantic and Gulf coasts of the United States,

- the chromium residues in Baltimore Harbor blue crabs do not pose a human health threat.

REFERENCES

- EA Engineering, Science, and Technology, Inc. 1986. Allied Baltimore Works Remedial Investigation Report, Volume II: Risk Assessment. July 1986. Prepared for Allied Baltimore Works by EA under contract to NUS Corporation.
- Eisler, R. 1986. Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85(1.6). Patuxent Wildlife Research Center, Containment Hazard Reviews Report No. 6. 60 pp.

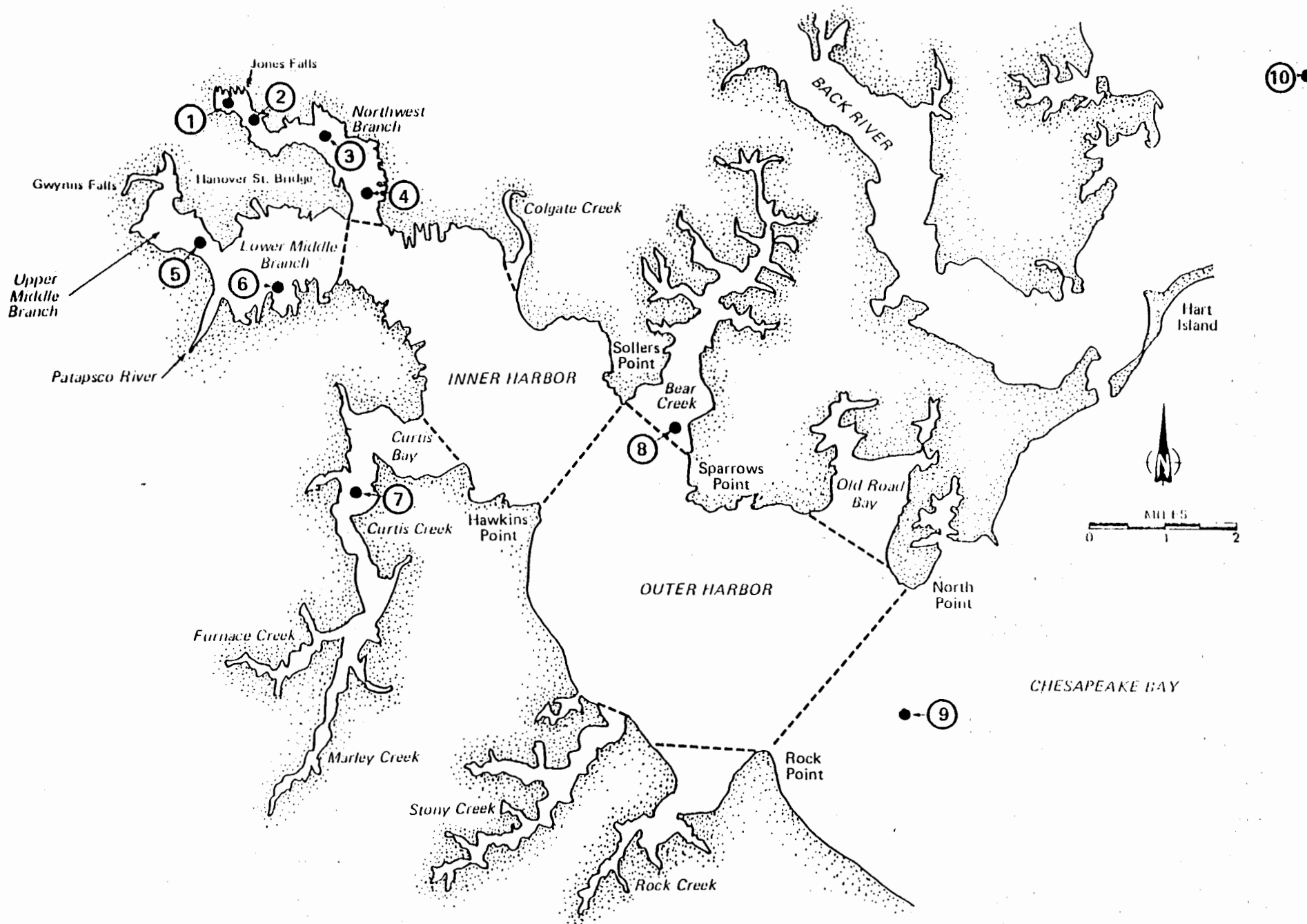


Figure 1. Locations of blue crab collection stations.

TABLE 1 BLUE CRAB BODY BURDEN, WATER COLUMN CONCENTRATION, AND SEDIMENT CONCENTRATION OF CHROMIUM
FOR SAMPLES COLLECTED IN BALTIMORE HARBOR, JULY 1986

Station ^(a)	N	Average Size (in.)	Sex M/F	Total Chromium Body Burden (mg/kg) ^(b)				Average Water Column ^(c) Concentration (mg/L)		Sediment ^(d) Concentration (mg/kg dry wt)	
				Wet Weight Basis		Dry Weight Basis					
				Average	Range	Average	Range	Cr(VI)	Cr. T	Cr(VI)	Cr.T
1	10	3.79	10/0	0.16	0.05-0.30	0.50	0.17-1.05	<0.02	0.04	0.30	1,300
2	10	4.07	4/6	0.58	0.20-1.20	1.60	0.54-3.37	0.06	0.30	0.93	1,900
3	10	4.19	6/4	0.20	0.05-0.50	0.51	0.10-1.20	<0.02	0.03	0.92	1,800
4	10	5.22	10/0	0.14	0.05-0.20	0.43	0.19-0.69	<0.02	<0.02	0.65	810
5	9	4.60	4/5	0.07	0.05-0.20	0.37	0.23-1.01	<0.02	<0.01	0.30	180
6	10	4.39	9/1	0.08	0.05-0.10	0.37	0.20-0.57	<0.02	<0.01	0.15	84
7	9	4.90	3/6	0.07	0.05-0.10	0.36	0.22-0.55	<0.02	<0.02	0.10	210
8	10	4.70	6/4	0.13	0.05-0.30	0.61	0.21-1.36	<0.02	<0.01	0.07	760
9	10	5.50	9/1	0.06	0.05-0.10	0.25	0.20-0.42	<0.02	<0.01	0.10	41
10	9	5.24	9/0	0.09	0.05-0.20	0.40	0.23-0.83	<0.02	<0.01	0.10	37

(a) See Figure 1 for station locations.

(b) When values were less than the detection limit, numbers used were detection limit multiplied by 0.5.

(c) Based on a mean of n = 2.

(d) Data from October 1985 survey (EA 1986).

TABLE 2 ANOVA AND TUKEY'S STUDENTIZED RANGE TEST RESULTS FOR TOTAL CHROMIUM BODY BURDEN (wet weight)
IN BLUE CRABS COLLECTED FROM BALTIMORE HARBOR, JULY 1986

Dependent Variable: Body burden -- Wet weight

<u>Source</u>	<u>DF</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F Value</u>	<u>PR > F</u>	<u>R Square</u>	<u>C.V.</u>
Model	9	2.167	0.241	16.76	0.0001	0.63	75.98
Error	87	1.250	0.014		ROOT MSE		
Corrected Total	96	3.417			0.120		

<u>Source</u>	<u>DF</u>	<u>Type I SS</u>	<u>F Value</u>	<u>PR > F</u>	<u>DF</u>	<u>Type III SS</u>	<u>F Value</u>	<u>PR > F</u>
Station	9	2.167	16.76	0.0001	9	2.167	16.76	0.0001

TUKEY'S STUDENTIZED RANGE (HSD) TEST FOR VARIABLE: Body burden -- Wet weight

ALPHA = 0.05 DF = 87 MSE = 0.0144

Critical Value of Studentized Range = 4.592

Minimum Significant Difference = 0.177

<u>Tukey Grouping</u>	<u>Mean</u>	<u>N</u>	<u>Station</u>
A	0.580	10	2
B	0.195	10	3
B	0.155	10	1
B	0.135	10	4
B	0.130	10	8
B	0.089	9	10
B	0.075	10	6
B	0.072	9	5
B	0.067	9	7
B	0.055	10	9

Means with the same letter are not significantly different.

TABLE 3 ANOVA AND TUKEY'S STUDENTIZED RANGE TEST RESULTS FOR TOTAL CHROMIUM BODY BURDEN (dry weight)
IN BLUE CRABS COLLECTED FROM BALTIMORE HARBOR, JULY 1986

Dependent Variable: Body burden -- Dry weight

<u>Source</u>	<u>DF</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F Value</u>	<u>PR > F</u>	<u>R Square</u>	<u>C.V.</u>
Model	9	13.170	1.463	11.63	0.0001	0.549	65.05
Error	86	10.822	0.126		ROOT MSE		
Corrected Total	95	23.992			0.355		

<u>Source</u>	<u>DF</u>	<u>Type I SS</u>	<u>F Value</u>	<u>PR > F</u>	<u>DF</u>	<u>Type III SS</u>	<u>F Value</u>	<u>PR > F</u>
Station	9	13.170	11.63	0.0001	9	13.17	11.63	0.0001

TUKEY'S STUDENTIZED RANGE (HSD) TEST FOR VARIABLE: Body burden -- Dry weight

ALPHA = 0.05 DF = 86 MSE = 0.126

Critical Value of Studentized Range = 4.594

Minimum Significant Difference = 0.527

<u>Tukey Grouping</u>	<u>Mean</u>	<u>N</u>	<u>Station</u>
A	1.596	10	2
B	0.607	10	8
B	0.507	9	3
B	0.503	10	1
B	0.431	10	4
B	0.403	9	10
B	0.375	9	5
B	0.370	10	6
B	0.356	9	7
B	0.251	10	9

Means with the same letter are not significantly different.

TABLE 4 ANOVA AND TUKEY'S STUDENTIZED RANGE TEST RESULTS FOR HEXAVALENT CHROMIUM CONCENTRATIONS
IN WATER SAMPLES COLLECTED FROM BALTIMORE HARBOR, JULY 1986

Dependent Variable: Cr,(VI) -- Water

<u>Source</u>	<u>DF</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F Value</u>	<u>PR > F</u>	<u>R Square</u>	<u>C.V.</u>
Model	9	0.0054	0.000045	13.44	0.0002	0.92	43.27
Error	10	0.00045	0.000605		ROOT MSE		
Corrected Total	19	0.0059			0.0067		

<u>Source</u>	<u>DF</u>	<u>Type I SS</u>	<u>F Value</u>	<u>PR > F</u>	<u>DF</u>	<u>Type III SS</u>	<u>F Value</u>	<u>PR > F</u>
Station	9	0.0054	13.44	0.0002	9	0.0054	13.44	0.0002

TUKEY'S STUDENTIZED RANGE (HSD) TEST FOR VARIABLE: Cr,(VI) -- Water

ALPHA = 0.05 DF = 10 MSE = 4.5E-05

Critical Value of Studentized Range = 5.599

Minimum Significant Difference = 0.026

<u>Tukey Grouping</u>	<u>Mean</u>	<u>N</u>	<u>Station</u>
A	0.065	2	2
B	0.010	2	1
B	0.010	2	3
B	0.010	2	4
B	0.010	2	5
B	0.010	2	6
B	0.010	2	7
B	0.010	2	8
B	0.010	2	9
B	0.010	2	10

Means with the same letter are not significantly different.

TABLE 5 ANOVA AND TUKEY'S STUDENTIZED RANGE TEST RESULTS FOR TOTAL CHROMIUM CONCENTRATIONS
IN WATER SAMPLES COLLECTED FROM BALTIMORE HARBOR, JULY 1986

Dependent Variable: Cr,T -- Water

<u>Source</u>	<u>DF</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F Value</u>	<u>PR > F</u>	<u>R Square</u>	<u>C.V.</u>
Model	9	0.155	0.017	1.53	0.257	0.58	248.31
Error	10	0.113	0.011		ROOT MSE		
Corrected Total	19	0.268			0.106		

<u>Source</u>	<u>DF</u>	<u>Type I SS</u>	<u>F Value</u>	<u>PR > F</u>	<u>DF</u>	<u>Type III SS</u>	<u>F Value</u>	<u>PR > F</u>
Station	9	0.155	1.53	0.257	9	0.155	1.53	0.257

TUKEY'S STUDENTIZED RANGE (HSD) TEST FOR VARIABLE: Cr,T -- Water

ALPHA = 0.05 DF = 10 MSE = 0.011

Critical Value of Studentized Range = 5.599

Minimum Significant Difference = 0.420

<u>Tukey Grouping</u>	<u>Mean</u>	<u>N</u>	<u>Station</u>
A	0.305	2	2
A	0.040	2	1
A	0.030	2	3
A	0.012	2	4
A	0.012	2	7
A	0.008	2	8
A	0.005	2	6
A	0.005	2	5
A	0.005	2	9
A	0.005	2	10

Means with the same letter are not significantly different.

CORRELATION COEFFICIENTS / PROB > R UNDER H0:RHO=0 / N = 10

[illegible]



RECEIVED
MD/DEPC SECTION

SEP 8 1986

U.S. EPA, Region III

7023

Allied Corporation
Block Street at Wills
Baltimore, MD 21231-3399
(301) 522-5200

BY HAND DELIVERY

September 5, 1986

Mr. Ronald Nelson, Director
Waste Management Administration
Office of Environmental Programs
201 West Preston Street
Baltimore, Maryland 21201

RECEIVED

SEP 08 1986

Hazardous Waste Management Division
EPA - Region III

Mr. Stephen R. Wassersug, Director
Hazardous Waste Management Division
United States Environmental Protection Agency
841 Chestnut Building
Philadelphia, PA 19107

Gentlemen:

Enclosed herewith are copies of the Remedial Investigation, Risk Assessment and Groundwater Monitoring Reports prepared by Allied Corporation for its Baltimore Works. These documents are being submitted in accordance with paragraph 4 of the Consent Order signed by Judge Murray of the U.S. District Court for the District of Maryland on September 2, 1986, in State of Maryland v. Allied Corporation. Civil Action No. 86-2571-HM.

Paragraph 4 of the Consent Order requires the Maryland Waste Management Administration ("WMA") to review the RI Report within 45 days, and Allied looks forward to receiving WMA's comments in accordance with the schedule.

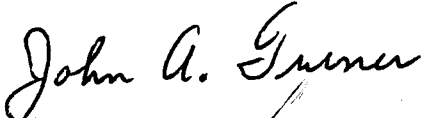
On August 6, 1986, U.S. EPA gave public notice of its intention to issue a RCRA hazardous waste storage permit to Allied's Baltimore Works. A public hearing has been scheduled and comments solicited on the draft permit, and it may be sometime before a final permit is issued. Part II A, B.1, and C of the draft permit call for submission by Allied of a Remedial Investigation and Risk Assessment within 30 days of the permit effective date. Allied believes the enclosed documents satisfy the requirements established in the draft permit. Although U.S. EPA has no obligation to do so, Allied asks that U.S. EPA review and provide comments on the documents simultaneously with WMA. This coordination will allow Allied to make any necessary revisions to the RI Report and begin work on the Feasibility Study without fear

Mr. Ronald Nelson, Director
Mr. Stephen R. Wassersug, Director
September 5, 1986
Page 2

that U.S. EPA will subsequently raise different concerns and make Allied redo the RI Report or subsequent documents. We appreciate your cooperation on this matter.

Please direct any questions concerning these reports to Mr. Mark Sylvester at (301) 522-5247.

Very truly yours,

A handwritten signature in cursive script that reads "John A. Turner".

John A. Turner
Site Manager

JAT:em
Enclosure
cc: Judge Murray (without enclosures)

EXECUTIVE SUMMARY

Allied processed chromium ore and manufactured chromium products at the Baltimore Works from 1954 until June 1985. The plant site has been involved in the processing of chrome ore since 1845. In recent times, on the order of 50,000 tons of product and 100,000 tons of waste were generated annually at the plant. The majority of waste was shipped off site for disposal although some (chrome ore tailings) was used for filling certain portions of the site.

Most products manufactured at the site produced hexavalent chromium wastes. A small portion of the total manufactured product involved production of Koreon[®] which is primarily trivalent chromium. The chrome ore tailings have the potential to leach chromium (a hazardous constituent) at levels up to 2000 mg/L, most of which is in the hexavalent form.

A preliminary study undertaken by Allied in 1984 to assess ground water and soils beneath the site indicated the presence of elevated levels of chromium in both media. Subsequent to this study Allied initiated a Remedial Investigation in late 1985 with the following objectives:

- (1) To describe the geologic and hydrogeologic characteristics of the site which may influence contaminant migration.
- (2) To assess the nature, extent, and magnitude of contamination on site and migrating from the facility.
- (3) To examine the potential for offsite migration of chromium downgradient of the site.
- (4) To provide engineering data to assist in the selection and design of appropriate remedial measures.

In response to these objectives, an extensive field investigation and laboratory program was undertaken. This program, which was begun in October 1985 and completed in May of 1986, included:

- o Drilling of 44 subsurface soil borings, 3 of which were off shore.
- o Installation of 28 ground water monitor wells and 3 off shore monitoring systems.
- o Excavation of 19 test pits.
- o Collection of 108 soil samples for chemical analyses and 45 for geotechnical testing.
- o Performance of both downhole and surface geophysical surveys.
- o Performance of aquifer tests on all wells.
- o Computer modeling of contaminant migration potential and analysis of collected data.

As a result of these activities the following principal conclusions have been drawn:

- (1) Chromium (predominantly hexavalent) is the principal chemical constituent of concern found in the soils and ground water at the Baltimore Works although trace quantities of other chemical constituents occurred randomly in the ground water.
- (2) Sources of significant leachable chromium include: the former plant site, north of Block Street; the chromic acid process area on the northwest corner of the site; and the south slip, which contains chrome ore tailings. In general, soils with EP Toxicity levels in excess of 5.0 mg/L occur in the northern and western portions of the site.
- (3) Ground water flow (and chromium movement) occurs such that movement is directed radially from the site through the bulkheads to the adjacent surface waters and sediment beneath the river. Flow direction is regionally influenced in the deeper ground water such that it is toward the

southeast, thereby carrying chromium beneath the river within the Patuxent aquifer. The maximum linear ground water velocity of the Patuxent aquifer in the site vicinity is estimated to be 18 ft/year.

- (4) Both shallow ground water (primarily within the fills) and deep ground water (primarily within the Patuxent Formation) have been affected. Both regimes have chromium concentrations in ground water beneath the major onsite source areas in excess of 5000 mg/L.
- (5) At present, ground water within the basal portion of the Patuxent, extending southeastward off site is affected by chromium contamination. This is indicated by the presence of chromium concentrations of 220 mg/L in ground water samples obtained from a remote sampling station (OB-3) located eighty feet from the site's southeast bulkhead, in the Patuxent aquifer underlying the Patapsco River.
- (6) Wells installed in the Patuxent aquifer no more than 3000 feet from the site and downgradient of the site showed no evidence of chromium above the EPA National Interim Primary Drinking Water Standard of 0.05 mg/L. Wells north, northwest, west and southwest of the site show little or no evidence of chromium.
- (7) Existing databases of well permits and ground water withdrawals in the site vicinity indicate the closest municipal drinking water supply in the Patuxent aquifer is the Glen Burnie system, some 8 miles south of the site. Two monitor wells between this municipal system and the site (within 5000 feet south of the site) exhibit chromium concentrations well below the drinking water standard.
- (8) Chromium migration off site into the surrounding Northwest Harbor waters generally has been found to be well below the water column mixing criteria. However, several point source leakage areas were observed in the vicinity of damaged bulkheads, which may cause localized high concentration conditions.

(9) The computer modeling effort predicts that an estimated 62 lb/day of chromium are leaving the site via ground water. Approximately 26 lb/day are contributed to the surface waters adjacent to the site, 24 lb/day are contributed to the adjacent river sediments, and 12 lb/day are contributed to the Patuxent aquifer.

(10) A 2-dimensional computer model prediction (based on continuous loading of chromium in current concentrations for 100 years) indicates that chromium in the Patuxent aquifer could migrate southeast to the Canton District 100 years from the present. This predicted plume is almost completely contained within the Patuxent aquifer chloride contamination zone, which already limits the present usefulness of the aquifer. The predicted plume not only progresses away from the Glen Burnie municipal drinking water wells but is predicted not to come within six miles of that system.

6.0 CONCLUSIONS

The RI report had several stated objectives. These were:

- o To describe the geologic and hydrogeologic characteristics of the site.
- o To assess the nature, extent, and magnitude of contamination on site and migrating from the facility.
- o To examine contaminant transport and fate mechanisms.
- o To provide a sound technical basis for evaluating appropriate remedial measures for mitigating site conditions.

The following conclusions were drawn with regard to these objectives.

Chromium is the principal chemical constituent of concern found in the soils and ground water at the Allied Baltimore Works, although trace quantities of other constituents occurred in the ground water. The occurrence of chromium on site is the result of various historic practices and a variety of sources. These sources include:

- o Areas where production or manufacture of chromium products occurred.
- o Areas where chrome ore tailings was used as fill.
- o Areas where these tailings were stored.

Principal areas where these sources occur and their associated suspected source types are summarized below.

- o The main plant parking area, where the original bichromate production facility stood until the 1950's, is suspected of being a significant source from both product losses and other leachable constituents.

- o The area west of the main plant parking area toward the chromic acid and Koreon[®] production area may contain variable amounts of chrome ore tailings and production operations residuals from the old manufacturing plant.
- o The northwest portion of the site which houses the chromic acid and Koreon[®] production areas is suspected of being a significant source of chromium from product losses.
- o The western portion of the bichromate production facility is a known area of significant chromium levels. Based on ground water contaminant data it appears there are both product and residue sources affecting this area.
- o The south slip area is known to have been filled with chrome ore tailings and is also a significant source of chromium in this portion of the site.

Additional areas around the site may contain leachable chromium sources. However, the major suspected source areas occur mainly along the northern and western portions of the facility. The southeastern portion of the site does not appear to be a significant source area.

In soils on site, the most significant levels of leachable chromium exceed total leachable chromium levels of 100 mg/L (EP Toxicity). These occur principally above elevation 0, and are associated with the north central, northwestern and west central portions of the site. Chromium levels above an EP Toxicity of 5.0 mg/L occupy the majority of the site in the northern and western portions. EP Toxicity levels remain high with decreasing elevation in the source areas. Non-source (EP Toxicity less than 5.0 mg/L) areas do not generally exhibit chromium levels above the EP Toxicity of 5.0 mg/L with decreasing elevation. An exception to this is where the ground water is contaminated at depth below the non-source area. It should be noted that the EP toxicity leachable levels of chromium may correspond to liquid infilling of soil pore spaces, especially in product source areas. Therefore, the EP toxicity procedure does not distinguish between liquid sources versus soil sources.

A significant portion of the leachable chromium on site is in the hexavalent form. However, it was observed that the EP Toxicity leachable level was not directly related to the total chromium concentrations in the soil. High levels of chromium in soil did not necessarily result in high EP Toxicity leachate levels.

Ground water chromium levels were found above the MCL's directly beneath the site. Both shallow ground water (primarily within the fills) and deep ground water (primarily within the Patuxent Formation) have been affected. Ground water within the fills was found to have chromium concentrations ranging from less than .01 mg/L to 14,500 mg/L. The shallow ground water exhibits chromium contamination generally coincident with the major source areas identified with the soil EP Toxicity testing. The deep ground water also exhibits higher chromium concentrations (in the thousands of mg/L) below the source areas. Deep regional flow has created migration of chromium to the southeast across the site and beneath the Northwest Branch (surface water) at levels of 50 to 200 mg/L.

Little or no migration of chromium (as evidenced by samples from wells and/or dedicated offshore samplers) has occurred to the north, northeast, west or southwest in the Patuxent.

Ground water concentrations of chromium in the wells screened within the marine silts are very low. This is thought to be attributable to the capacity of these sediments to adsorb chromium.

The geologic units which were interpreted to occur on the site include (in order of descending elevation):

- o Recent fills.
- o Pleistocene marine silts.
- o Pleistocene coarse grained sediments (sands and gravels).
- o Patuxent sands, silts, clay, and gravel.
- o Saprolite/Bedrock.

There are two ground water regimes beneath the site. The shallow ground water regime, principally occurring above the low permeability silts (which occur adjacent to the site perimeter but not in the center of the site) is interpreted to have flow directions radially off the site toward (and through) the bulkheads.

The deeper ground water regime occurs principally within the Pleistocene coarse grained and Patuxent sediments. Regional flow for this aquifer originates northwest of the site and flows to the southeast beneath the site. Local site flow within this aquifer also occurs such that a radial component similar to the shallow flow regime exists. Additionally there is a significant downward (vertical) component of flow on the site which tends to enhance downward migration of shallow ground water principally in the center of the site.

Movement of chromium in ground water, therefore, is interpreted to occur such that flow is:

- o Directed radially out of the site through the bulkheads to the adjacent surface waters or sediment beneath the river.
- o Regionally influenced in the deeper ground water such that flow direction is toward the southeast, thereby carrying contaminants beneath Northwest Branch surface waters within the Patuxent aquifer.

Three wells were installed within 3000 feet of the site (located in both current and historic downgradient areas to the east, south, and southeast). None of the samples collected from these wells showed evidence of chromium above aquifer background, thus delineating the extent of impact of chromium within the aquifer. This confirmed a 1982 study on ground water samples collected from the Patuxent aquifer on a regional basis which indicated background chromium concentrations between .001 and .006 mg/L. This further substantiated that the chromium originating onsite within the aquifer was limited areally in a regional sense. The estimated existing extent of chromium in the Patuxent aquifer is wholly contained within the chloride contamination zone.

Additional investigation was performed utilizing computer searches by the State of Maryland for both ground water withdrawal permits and well installation permits within a 10 mile by 10 mile grid and a 5 mile by 5 mile grid, respectively. The closest municipal supply of drinking water (the Glen Burnie System) was found to be some 8 miles south of the site, far from any impacts indicated by this investigation. Two downgradient monitor wells less than 5000 feet south of the site exhibit chromium concentrations well below the MCL of 0.05 mg/L.

Once the magnitude and extent of both shallow and deep ground water systems was assessed, a computer modeling effort was initiated. This effort resulted in estimates of the chromium loading rate off the site on a daily basis. It also predicted the potential movement of chromium in the Patuxent aquifer to the southeast from the present to 100 years from the present.

Assuming worst case conditions, the movement of chromium downgradient of the site (based on current aquifer use conditions and continued site constant chromium load) is predicted to extend into the Canton District (generally parallel to Northwest Branch) within 100 years from present. The predicted plume in the Patuxent 100 years from present is generally contained within the chloride contamination zone of the Patuxent aquifer (as depicted by Chapelle, 1985). However, the chromium plume may diffuse beyond the 250 mg/L chloride isoconcentration level toward the northwest 100 years from the present. The predicted chromium plume extends southeast (away from the Glen Burnie municipal supply system) and is predicted to come no closer than 6 miles of the Glen Burnie system, the only public water supply utilizing the Patuxent Aquifer in the Baltimore region.

The modeling effort indicates that an estimated 62 lb/day of chromium is leaving the site via ground water. Approximately 26 lb/day is contributed to the surface waters adjacent to the site, 24 lb/day is contributed to the adjacent river sediments, and 12 lb/day is contributed to the Patuxent aquifer. An assessment of possible risks to human and environmental receptors due to chromium migrating from the site is presented in Volume Two.

EXECUTIVE SUMMARY

EA Engineering, Science, and Technology, Inc. evaluated the risks to humans and to the aquatic environment due to exposure to chromium releases from the Allied Baltimore Works on Baltimore Harbor. NUS Corporation conducted extensive site characterizations defining the onsite sources of chromium and the releases of this material into surface and ground waters. These analyses will serve as inputs to a subsequent engineering feasibility study addressing site closure issues.

APPROACH

Measured onsite chromium levels in surficial soils were used to estimate chromium emissions, ambient air concentrations, and resultant risk to humans both at the site boundary and at the nearest residence to the site.

The estimated ground-water releases of chromium into surface water were used along with measured chromium concentrations to predict effects on estuarine organisms and to estimate potential exposures to swimmers in these nearshore waters.

Chromium residues in blue crabs living throughout the Baltimore Harbor were measured. The results were compared to chromium levels in crabs from other geographical areas and were used to estimate human exposures via eating these crabs.

Estuarine benthic communities were evaluated both adjacent to the Allied site and in comparable habitats outside the direct influence of chromium released from the site.

KEY FINDINGS

Human Health Risk

The incremental carcinogenic and noncarcinogenic risk to humans associated with emissions of trivalent chromium [Cr(III)] and hexavalent chromium [Cr(VI)] from the Baltimore Works were quantified for both current site conditions and potential earthmoving activities.

- . For noncarcinogenic effects, the combined daily intake of both Cr(III) and Cr(VI) via all exposure pathways is well within the limits of the Acceptable Daily Intake.
- . Average modeled air concentrations of chromium estimated to occur at the site perimeter and at the nearest residence are below air concentrations associated with noncarcinogenic respiratory tract effects.
- . For offsite human receptors, the predicted excess cancer incidence resulting from one year's inhalation of Cr(VI) in fugitive windblown dust is 0.005 in one million (i.e., 5×10^{-9}). For a hypothetical resident spending 70 years directly downwind of the site, the predicted age-adjusted lifetime excess cancer incidence from uncontrolled fugitive windblown dust is 0.73 in one million people (i.e., 7.3×10^{-7}).
- . For offsite human receptors, the highest mean predicted excess cancer incidence resulting from uncontrolled emissions from projected mechanical resuspension of dust would be 0.022 in one million people (i.e., 2.2×10^{-8}).

Impact on Aquatic Life

The environmental risk to the estuarine biological community was examined by comparing hexavalent chromium concentrations in the water column to acute and chronic toxic effect levels for saltwater organisms.

- . The Northwest Branch is a low-salinity estuarine area which has been adversely affected by the extensive industrial and urban areas which surround it. Although there are many point and nonpoint sources of pollutants along the Northwest Branch, discharges from the Allied Baltimore Works have probably contributed to the degraded conditions that exist in the water column and sediments adjacent to the site.
- . Acutely toxic effects on aquatic organisms are not expected.
- . Concentrations of Cr(VI) measured may exceed those levels associated with chronically toxic effects to aquatic organisms. Measured exceedances of Cr(VI) concentrations over EPA's 4-day average criterion for saltwater aquatic life are limited to a cross-sectional area of less than 10 percent of the Northwest Branch, which would satisfy Maryland's estuarine mixing zone regulations, an analogous criterion of acceptable conditions.
- . Modeled steady-state chromium concentrations predicted for the Northwest Branch exceed EPA's chronic (4-day) criterion for the protection of saltwater aquatic life, but only during short-term (less than 36-hour duration), transient surface water conditions.

- . While there is some evidence of elevated chromium levels in edible tissues of blue crabs in the Northwest Branch, these levels are within the range of chromium concentrations found in blue crabs from the Chesapeake Bay and other geographic areas and in other estuarine and marine crustaceans. The levels of chromium residues in the crabs from Baltimore Harbor do not pose a human health threat.

Impact on Ground Water

NUS estimated chromium releases to the Patuxent aquifer from the Allied Baltimore Works and modeled the chromium plume movement from 1986 through 2086, at 20-year intervals.

- . Model results showed that the area of the aquifer currently containing concentrations greater than or equal to the present chromium drinking water criterion (interim maximum contaminant level, MCL) of 50 µg/L lies within the area of the Patuxent aquifer that is already contaminated with chlorides greater than 250 mg/L. Because this chloride contamination precludes potable water use of this ground water, this use is not currently considered as a source of human exposure (and consequent risk).
- . In 2086, almost all of the area of the aquifer that contains greater than 50 µg/L chromium will still lie within the chloride contaminated area if chromium discharge and aquifer pumping conditions remain constant over the next 100 years. A small portion of the chromium plume north and west of the Allied Baltimore Works site may extend less than 500 feet beyond the chloride contaminated region.
- . EPA has proposed a recommended maximum contaminant level (RMCL) for chromium of 120 µg/L. This is the initial step to setting a final drinking water MCL. If EPA adopts this

value as the MCL, all of the area exceeding the MCL for chromium will probably be contained within the zone of chloride contamination.

Implications for the Feasibility Study

The risk assessment has demonstrated that existing conditions at the Allied Baltimore Works do not result in unmanageable human health or environmental problems. However, adverse effects noted above could be addressed by the following steps:

- . Site activities, such as earth moving, should be designed and managed to minimize fugitive emissions from the site.
- . Reduction of chromium releases to the surface water adjacent to the site should improve long-term surface water quality, but may have little effect on overall sediment quality.
- . Current ground-water contamination by chromium does not have any current human health implications, but may present loss of a potential resource for some kinds of industrial uses. Limitation of the ground-water chromium plume migration would reduce this natural resource loss as well as any potential future human exposure to chromium-contaminated ground water.

DRILL, FRIESS, HAYS, LOOMIS & SHAFFER, INC.

CONSULTANTS IN TOXICOLOGY

Seattle Office
2707 E. Becker Rd.
Clinton, WA 98236
(206) 321-5175

Chicago Office
1620 Meadow Lane
Glenview, IL 60025
(312) 724-5468

1901 N. Fort Myer Drive
Suite 204
Arlington, Virginia 22209
Phone (703) 527-6450

FORWARD

This assessment of risk to human health and the environment was conducted under the direction of a Steering Committee whose members are listed below. The environmental data generated by the NUS Corporation Remedial Investigation, provided the basis and the Committee developed the framework, assumptions and limitations of this assessment. This study represents the appropriate application of scientific risk assessment principles to the Allied Corporation, Baltimore Works situation, and provides an excellent foundation for the Engineering Feasibility Study and Closure Plan.

Steering Committee

W.E. Rinehart, Sc.D., DABT, Director
Toxicology Department (Retired)
Allied-Signal Corporation

J.J. Gift, Ph.D.
Vice President
EA, Engineering Science
& Technology

G.V. Loewengart, Ph.D., DABT
Manager, Toxicology Department
Allied-Signal Corporation

J.C. Baummer, Ph.D.
Project Manager
EA, Engineering Science
& Technology

W.E. Yanovitch, Director
Pollution Control
Engineered Materials Sector
Allied Corporation

M.A. Sylvester
Environmental Engineer
Baltimore Works
Allied Corporation

G.V. Gartseff
Project Manager
NUS Corporation


Seymour L. Friess, Ph.D.
Chairman

1. INTRODUCTION

The human health and environmental risk assessment presented here is a key element of the present remedial investigation of the decommissioned Allied Baltimore Works on Baltimore Harbor. This assessment addresses the potential effect of various chromium releases from the existing sources at the plant site on the surrounding community and aquatic populations of the Harbor. Environmental and human health risks are estimated based on results of the remedial investigation conducted by NUS Corporation, which defined the levels of chromium at the site and the various releases of the material into surface and ground waters. EA Engineering, Science, and Technology, Inc. has evaluated the potential effects of these releases. This assessment serves as both an analysis of current site conditions and as an analytical framework for evaluating the risks during the subsequent engineering feasibility study to be conducted at the site.

This risk assessment is divided into ten chapters. Chapter 2 briefly describes the background for the assessment, summarizes site conditions, summarizes the general basis for concern with regard to releases from the site, and outlines the regulatory framework which has to be addressed in making this assessment. Chapters 3 and 4 summarize the key findings of the NUS remedial investigation and the results of both the three-dimensional modeling of near-field chromium releases and the far-field two-dimensional modeling addressing the presence of chromium in the deeper ground-water aquifers. Chapter 5 presents estimates of far-field, steady-state chromium concentrations in surface waters based on modeling of the releases of chromium from the site, and estimates of chromium concentration close to the Allied site from a field study measuring total and hexavalent chromium concentrations under three tidal conditions. Chapter 6 addresses mass loadings of chromium into Baltimore Harbor. This chapter places the present loadings of chromium to the Harbor from the Allied site into perspective with other known sources of chromium. Chapter 7 addresses airborne chromium concentrations which may result from various activities at the site. Chapter 8 reviews the fate of chromium in the environment; it includes a literature review (addressing

fate in the soil, air, and water), and presents the results of site-specific laboratory studies, which examined the potential for conversions between trivalent and hexavalent chromium in Baltimore Harbor water. Chapter 9 addresses risk from chromium releases to the marine environment adjacent to the site. This environmental risk assessment addresses: (1) near-field and far-field water column toxicity, (2) tissue levels of chromium in aquatic organisms, and (3) the localized benthic invertebrate community response adjacent to the plant site. Chapter 10 addresses the risk to humans of chromium releases from the site. This chapter presents an overview of the toxicity of chromium to man, quantitatively evaluates human exposure to chromium from site releases, and estimates potential carcinogenic and noncarcinogenic risks to humans from these different exposure routes. Chapter 11 provides a brief summary of key findings of this overall risk assessment and their implications for issues which should be addressed in the subsequent engineering feasibility study.

11. IMPLICATIONS OF RISK ASSESSMENT FOR THE ENGINEERING FEASIBILITY STUDY

This risk assessment is based on

- . Projected releases of chromium from the Allied Baltimore Works site
- . Measured surficial soil and surface water chromium concentrations
- . Modeled ground water, surface water, and air concentrations of chromium
- . Predicted intensities and frequencies of human exposures
- . Predicted intensities and frequencies of aquatic organism exposures

The risk assessment found that the surface-water concentrations of hexavalent chromium are below the levels expected to cause acute effects in estuarine organisms, but could cause chronic effects in sensitive water column species within 600 feet of the site. The chronic effects are confined to the area within 10 percent of the cross-sectional area of the Northwest Branch (which satisfies the Maryland Water Quality Standard for mixing zone size). Surface-water concentrations of hexavalent chromium also exceed the chronic (4-day average) criterion near the site, based on steady-state modeling of transient meteorological conditions (i.e., conditions lasting less than 36 hours). A depauperate benthic community was found in the sediment adjacent to the site. These sediments have high concentrations of chromium.

The human risk assessment found that noncarcinogenic systemic toxicity should not be a concern because total daily intakes of total chromium are well below calculated Acceptable Daily Intake levels. Swimming in surface waters adjacent to the site contributed the largest daily intake,

but this contribution represents, at most, 11 percent of the calculated Accepted Daily Intake. Currently, fugitive windblown dusts are the only sources of carcinogenic risk to the community. Predicted mean levels of Cr(VI) inhaled over a 70-year lifetime result in a risk of 7.3×10^{-7} . The mean air chromium concentrations are below levels associated with noncarcinogenic respiratory tract effects. For mechanical resuspension of dust, based on predicted mean airborne chromium emissions from potential earthmoving activities, the maximum predicted risk is 7.8×10^{-7} . The concentrations of inspirable chromium are below those concentrations associated with noncarcinogenic respiratory tract effects.

The plume of chromium-contaminated ground water is expected to expand over the next 100 years. This chromium should not have any human health implications because the ground water is currently unpotable because of pre-existing chloride contamination. In addition, at present, the ground water may not be suitable for certain industrial uses because of the chromium contamination. However, if no remedial steps are taken, the potential does exist in the distant future for chromium contamination to remain in the aquifer after dilution begins to reduce the concentration of chlorides to acceptable levels.

The implications of these risk assessment results to the engineering feasibility are

1. Ground Water--Restriction of the contaminated ground water plume and/or remediation of the source of chromium would minimize both the potential for future human exposure to contaminated ground water and the potential natural resources loss of the ground water.
2. Surface Water--Reduction of the releases of the chromium into surface water adjacent to the site would reduce chronic effects on the water column species as well as the human daily intake of chromium through swimming. This reduction would have little immediate effect on either the sediment loads of chromium or the depauperate

benthic community. The benthic community may not recover even if chromium releases are eliminated because of the generally poor habitat quality of the Northwest Branch.

3. Ambient Air--Windblown particulate dust poses an excess lifetime carcinogenic risk of 7.3×10^{-7} for a 70-year resident. The potential mechanical resuspension emissions discussed in this study are projected to generate an excess cancer incidence of less than 8×10^{-7} and no non-carcinogenic respiratory effects are anticipated. If these or similar earthmoving activities are considered as part of a site development or remediation plan, an analysis of fugitive dust emissions should be conducted based on the specific equipment and soil removal volume designated during the engineering plans.
4. Surficial Soils--During earthmoving activities, unprotected workers may experience skin effects due to contact with contaminated soils and ground water. Implementation of proper safety and industrial hygiene practices can minimize these concerns. If there is to be public access to the site, steps should be taken to prevent direct contact with contaminated soils.

12. TECHNICAL SUMMARY

EA Engineering, Science, and Technology, Inc. evaluated the risks to humans and to the aquatic environment from exposures to chromium released from the Allied Baltimore Works on Baltimore Harbor. These analyses will serve as inputs to a subsequent engineering feasibility study addressing site-closure issues.

12.1 APPROACH

12.1.1 NUS Remedial Investigation

The NUS remedial investigation of the Allied site characterized the chromium concentrations in surficial soils, ground water, and near-site ground water. The ground-water data were evaluated using a three-dimensional model to estimate releases into the Northwest Branch of the Patapsco River and the Patuxent aquifer.

The current releases to the surface waters adjacent to the plant site are approximately 11.7 kg/day (25.8 lb/day). Approximately 16.5 kg/day (36.4 lb/day) of chromium is discharged into silts beneath the water column and into the aquifer. The movement of this chromium through the aquifer during the period 1986-2086 was estimated using this loading with a two-dimensional, ground-water dispersion model. This latter analysis showed that in 1986 the area of the ground-water plume containing at least 50 µg/L total chromium (current chromium drinking water criterion concentration) should always be within the area of the Patuxent aquifer which is already contaminated with at least 250 mg/L chlorides. This area of chloride contamination exceeds the drinking water criterion for chlorides. Thus, this water source is not likely to be used as potable. Consequently, the localized chromium-contaminated portions of the Patuxent aquifer have not been further addressed as a current source of human exposure to chromium. By 2086, the chromium-contaminated region of the Patuxent aquifer may extend beyond that region contaminated with chlorides. The nature of the NUS model output as a worst-case estimate should be viewed accordingly. The model incorporates assumptions such

as a constant, continuing chromium plume with no impeding physiochemical processes, clearly providing for a worst-case scenario. Due to the other generalized contamination of the aquifer, the abundance of the public water supply, and the worst-case nature of the model, potable use is viewed as unlikely. However, the potential for nonpotable use of contaminated ground water is considered.

12.1.2 EA Investigations

Distribution of Chromium in Surface Waters--The distribution of chromium in surface waters adjacent to the plant was estimated with two separate approaches. First, a dispersion model developed for the Northwest Branch by Robert Wilson at the Chesapeake Bay Institute was used to evaluate the steady-state distribution of chromium entering the Northwest Branch from the Allied site. This prediction provided a steady-state estimate of the Allied Baltimore Works contribution to the water-column chromium concentrations in this section of the Harbor. Second, a near-field water quality monitoring study (i.e., within 600 feet of the bulkhead) was performed to measure chromium concentrations in waters adjacent to the site under three tidal conditions.

The Wilson model projected that incremental chromium concentrations were likely to be highest in the inner Northwest Branch above (i.e., toward the Harbor head) and adjacent to the Allied plant site. During the most frequently occurring types of circulation, the Allied site contributions to the chromium concentrations would always be less than 20 µg/L. In contrast, during short periods of high flow, in Jones Falls, modeled concentrations in the innermost reaches of the Northwest Branch would exceed 100 µg/L chromium, while most of the Northwest Branch would still contain less than 20 µg/L. The infrequent short-lived circulation pattern generally lasts less than 36 hours.

EA measured near-field water column chromium at three depths under three tidal conditions. Under two tidal conditions and at all depths, the region where hexavalent chromium concentration exceeded 50 µg/L, the

Saltwater 4-day average (chronic criterion) for hexavalent chromium, was confined to areas relatively close to the western bulkhead and north of the plant site. During the low-tidal conditions with high northwesterly winds, the surface-water area exceeding 50 µg/L chromium concentration extended southeasterly down the Northwest Branch away from the plant site. For comparative purposes, the hexavalent chromium concentration data for all three tidal conditions were examined for compliance with the Maryland cross-sectional mixing zone criterion for point-source discharges. Under all three tidal conditions, the cross-sectional area encompassed by the 50 µg/L contour was less than 10 percent of the cross-sectional area of the Northwest Branch which is the Maryland Water Quality Standard for mixing zone size.

The results of the steady-state and near-field chromium water analyses were used to estimate the effects on the estuarine environment and to assess the risk to the community.

Mass Loading of Chromium into Baltimore Harbor--The loadings of chromium from the Baltimore Works into the Northwest Branch and into Baltimore Harbor were put into perspective by examining this loading relative to chromium mass loadings from other known discharges into these areas. The release of chromium into surface waters from the Allied site is the major identifiable source of chromium into the Northwest Branch of the Patapsco River (87 percent). However, the Allied site contributes only about 8 percent of the total known loadings of chromium to the tidal portion of the Patapsco River.

Crab Body-Burden Study and Benthic Invertebrate Studies--EA collected blue crabs from four stations in the Northwest Branch and six stations in the Outer Harbor and Chesapeake Bay. These crabs were steamed and picked as if they were to be eaten. The edible tissue was then analyzed for chromium residues. Although there was a significant statistical difference between the Northwest Branch crabs and the Outer Harbor/Chesapeake Bay crabs, all chromium body burdens found were within levels common to crabs from other areas of the Atlantic Coast.

Benthic invertebrate communities were sampled at two sites adjacent to the Allied Baltimore Works and three other stations further into the Northwest Branch. The organisms collected were identified, and the number of taxa, community richness, community evenness, and community diversity were assessed. All of the communities examined showed signs of stress (e.g., low species diversity, few organisms per species), but those organisms nearest the Allied Baltimore Works showed the lowest level of community quality.

The fate of chromium in the Baltimore Harbor environment was examined by reviewing literature studies and site-specific laboratory experiments. The literature revealed that the ultimate fate of chromium and the transitions between trivalent and hexavalent forms are related to site-specific conditions, such as pH, and the presence of oxidizing agents, reducing agents, and manganese.

EA conducted laboratory studies to determine the potential for Cr(VI) to be released from the Harbor sediment to the water column; the ability of suspended sediment to act as a sink for chromium; and the kinetics of chromium oxidation/reduction transformations in the Baltimore Harbor water column. The results indicated that very little of the chromium in Harbor sediment is likely to be released in soluble form; instead, suspended sediment may play a role in removing Cr(VI) from the water column. In the absence of appreciable concentrations of suspended matter, organics, or sulfide, hexavalent chromium is stable in Baltimore Harbor water, exhibiting little potential for transformation to trivalent insoluble forms.

Airborne Chromium--Airborne chromium releases from the site were estimated, based on surficial soil concentrations of total and hexavalent chromium, and screening-level emissions and dispersion models. Windblown erosion of site soils and fugitive emissions associated with a potential earthmoving scenario were evaluated to predict human exposures at the site and at workplaces and residences in the surrounding area.

Human Health Effects Review--The scientific literature on the effects of chromium on humans was reviewed. This review determined that there are four potential human health end points to be evaluated.

1. The development of cancer resulting from inhalation of hexavalent chromium
2. The occurrence of noncarcinogenic respiratory tract effects resulting from inhalation of hexavalent chromium
3. The occurrence of skin effects (sensitization and ulceration) resulting from dermal contact with chromium
4. Kidney damage (or other systemic toxicity reactions) resulting from inhalation, ingestion, and/or dermal contact with either hexavalent chromium or trivalent chromium

12.2 RISK ASSESSMENTS

12.2.1 Impact on the Aquatic Environment

The impact on the aquatic environment was assessed for potential toxic effects of chromium releases from the Allied site on the water column organisms and on the near-field benthos communities of the Northwest Branch. These assessments compared both measured and modeled hexavalent chromium concentrations in the water column to both acute and chronic toxic effect levels for water column species. Based on measured near-field hexavalent chromium concentrations, acute toxicity effects are not expected, but near-field chronic effects are likely. However, the area of the water column containing hexavalent chromium at concentrations greater than 50 µg/L (chronic saltwater criterion) is likely to be limited to a cross-sectional area of less than 10 percent of the Northwest Branch.

Modeled steady-state chromium concentrations exceed the chronic (4-day average) criterion near the Allied site only during transient conditions persisting less than 36 hours. When modeled steady-state concentrations are compared to chronic dose-response data for the more sensitive salt-water species, reported chronic effects concentrations are equaled or exceeded in many areas of the Northwest Branch. However, these sensitive species are not likely to be found in low salinity waters such as Baltimore Harbor.

Although there was some evidence of elevation of chromium levels in the edible muscle tissues of blue crabs in the Northwest Branch as compared to Outer Harbor crabs, the levels found throughout the Harbor were below or within the range of chromium concentrations found in estuarine and marine crustacea in the Atlantic Ocean and Gulf of Mexico. The concentrations found by EA were also below the blue crab chromium body burdens found by the Maryland Department of Health and Mental Hygiene during a similar 1983 survey of Inner Harbor crabs. The highest muscle tissue chromium level measured was below 4 mg/kg total chromium, which is the level identified in the literature as providing presumptive evidence of chromium contamination.

Results of a near-field benthic and invertebrate community study at five Northwest Branch stations indicate that the Northwest Branch has a stressed benthic community. The number of taxa and the diversity of organisms were lowest at two stations near the Allied site. The results of this benthic survey were comparable to previous studies and indicate overall stressed conditions in Northwest Branch benthic populations.

The Northwest Branch of the Patapsco is a low-salinity estuarine area which has been adversely affected by the extensive industrial and urban areas that surround it. Although there are numerous other point and nonpoint sources of pollutants to the Northwest Branch, releases from the Allied site are probably a significant contributor to the degraded near-field conditions that exist in both the water column and the adjacent sediment.

12.2.2 Risk to Humans

The incremental carcinogenic and noncarcinogenic risk to man associated with emissions of Cr(III) and Cr(VI) from the Allied Baltimore Works was evaluated quantitatively for both current site conditions and potential earthmoving activity. Exposure pathways addressed during current conditions are inhalation of windblown fugitive dust, consumption of crabs from Baltimore Harbor, and swimming in the North Slip adjacent to the site. Exposure pathways addressed in conjunction with earthmoving activity are inhalation of fugitive dust generated, consumption of crabs from Baltimore Harbor, and swimming in the North Slip adjacent to the site.

Carcinogenic risk associated with respirable particulate hexavalent chromium ($<10\text{ }\mu\text{m}$ aerodynamic diameter) was calculated. The EPA Carcinogen Assessment Group's carcinogenic potency factor was used in this assessment. For windblown dust, the mean case estimates of risks for 1-year exposures of non-Allied workers, adult residents, child residents, and infant residents were all less than $\sim 1.3 \times 10^{-8}$. The age-weighted lifetime risk for a resident, assuming he spent his 70-year lifetime 500 meters in the prevailing wind direction downwind of the site, was estimated at 7.3×10^{-7} .

For earthmoving activities with no dust suppression measures, the carcinogenic risks were calculated on the basis of either two months and one year of exposure with emissions occurring eight hours a day, five days a week. The highest risk identified for a non-Allied worker or resident of any age was 7.8×10^{-7} for a 2-month exposure.

To evaluate systemic toxicity, EA calculated acceptable daily intake (ADI) for hexavalent and trivalent chromium based on appropriate animal studies. Even under maximum daily intakes assuming additive interactions of trivalent and hexavalent chromium effects, the estimate of daily intake is well below the levels necessary to cause effects based on ADIs.

Skin effects (sensitization and ulceration) might develop in unprotected workers who are in direct contact with onsite soils and ground water.

The potential for these responses can be minimized by the use of safety equipment and the proper safety precautions. Skin effects should not occur among residents of the surrounding community because these populations would not come into direct contact with contaminated soils and ground water.

Noncarcinogenic respiratory tract effects can occur in very sensitive people at ambient air concentrations as low as 2.5-10 $\mu\text{g}/\text{m}^3$. Estimates of worst-case hexavalent chromium concentrations at distances of 300 and 500 meters from the site are 0.6 and 0.3 $\mu\text{g}/\text{m}^3$, respectively, during earthmoving activities. These concentrations are below levels shown to cause effects.

12.2.3 Assessment of Nonpotable Uses of Chromium-Contaminated Ground Water

The Patuxent Aquifer underlying the Baltimore District and the Canton area is generally polluted, containing chloride, iron, arsenic, chromium, barium, manganese, trichloroethylene, and benzene at concentrations greater than the respective drinking water standards. In addition, there is abundant water available for nonpotable use through Baltimore City's municipal water supply. For these reasons, future nonpotable use of Patuxent Aquifer water was not evaluated.

12.3 IMPLICATIONS FOR FEASIBILITY STUDY

The implications of these risk assessment results to the engineering feasibility are

1. Ground Water--Restriction of the use of chromium contaminated ground water and/or remediation of the source of chromium should minimize both the potential for future human exposure to contaminated ground water and the natural resource loss of the ground water.

2. Surface Water--Reduction of the releases of chromium into surface water adjacent to the site should reduce both chronic effects on the water column species and the human daily intake of chromium through swimming. This reduction should have little immediate effect on either the sediment load of chromium or the depauperate benthic community. Even if chromium releases are eliminated, the benthic community may not recover due to the generally poor water quality and sediment conditions of the Northwest Branch.
3. Ambient Air--Windblown particulate dust poses a lifetime carcinogenic risk of 7.3×10^{-7} . Remedial activities reducing or eliminating the source of the dust should maintain risks below 1×10^{-6} . Mechanical resuspension of dust due to earthmoving activities as specifically defined in this study do not create cancer risks greater than 1×10^{-6} or noncarcinogenic respiratory tract effects. These site activities could be included as part of remedial procedures. If these or similar earthmoving activities are considered, a re-analysis of fugitive dusts should be conducted based on the specific equipment and daily soil volume removal designated during the engineering plans.
4. Surficial Soils--During earthmoving activities, unprotected workers may experience skin effects due to contact with contaminated soils and ground water. Implementation of proper safety and industrial hygiene practices should minimize these concerns. If there is to be public access to the site, steps should be taken to prevent direct contact with contaminated soils. If land uses other than the current one are considered as part of the feasibility study or remedial activities, other potential routes of exposure not considered in this study should be examined.